

POST HARVEST TECHNOLOGY

Concept

Crop production methods consist of two sub-methods like crop production and post-harvest operations activities. If harvesting covers the period when the various products have grown are removed from the field, after maturity, the post-harvest period runs from exit from the field to the time of culinary preparation. The efficiency of food production system can be increased by increasing the technical efficiency of the crop production system, i.e. reducing the technical inefficiency as well as increasing the efficiency of postharvest operations ultimately, i.e. reducing postharvest losses of the crop. This implies that considerable emphasis should be given not only on the crop production but also on the post-harvest operations.

The term “post-harvest” relates to the phase of a food supply system that connects the moment of harvest with the moment of consumption. A system is usually thought of as a set of things that work together as part of a mechanism that forms an integrated whole and is itself part of a network of other systems. A postharvest system is, therefore, a purposeful collection of participants, facilities, technologies and processes that deliver harvested products to their consumers.

Post-harvest technologies constitute an inter-disciplinary science and techniques applied to agricultural commodities after harvest for the purpose of preservation, conservation, quality control/enhancement, processing, packaging, storage, distribution, marketing, and utilization to meet the food and nutritional requirements of consumers in relation to their needs.

Therefore, a post-harvest technology is a series of processes as a part of crop cultivation cycle (referring to figure 1), and any handling techniques or treatments applied to the economic part of a crop just harvested from the field for the purpose of transforming it into a form, condition, or composition that adds value, makes it storable or prolongs its shelf-life, and makes it useable or edible.

However,

- Appropriate production practices are needed for good quality commodities
- Quality cannot be improved after harvest, only maintained.

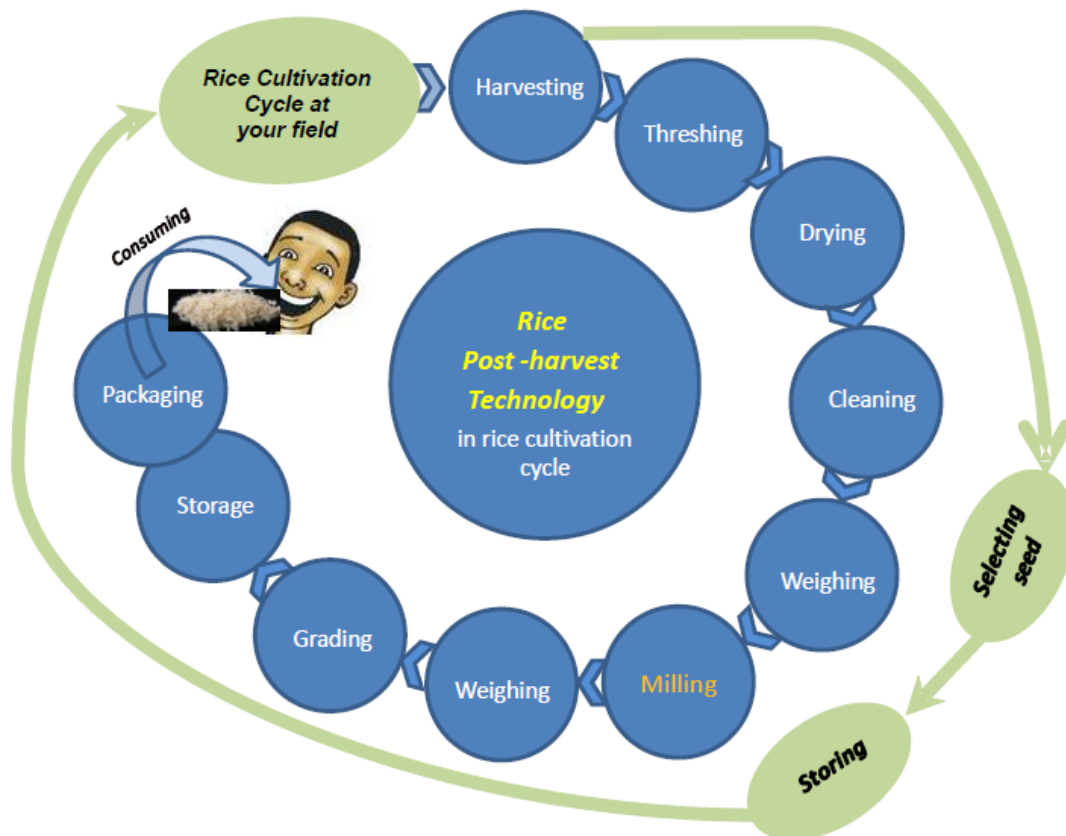


Figure 1. Illustration of different stages of rice post-harvest techniques and handling stages

LEARNING OBJECTIVES of this course

In this course, we will build knowledge and skills in:

- ❖ Assessing postharvest losses and quality problems for crops
- ❖ Accessing online resources on postharvest information and extension
- ❖ Identifying small-scale postharvest technologies and potential solutions which are most appropriate for local target groups
- ❖ Performing Cost / Benefit calculations for assessing the economic feasibility of recommended postharvest technologies
- ❖ Designing postharvest demonstrations to show farmers, traders, and marketers how to reduce losses, maintain quality and market value, increase shelf life and incomes

The **post-harvest system** encompasses a sequence of activities and operations that can be divided into two groups:

- **Technical activities:** harvesting, field drying, threshing, cleaning, additional drying, storage, processing;
- **Economic activities:** transporting, marketing, quality control, nutrition, extension, information and communication, administration and management.

Perspectives in a postharvest system

Unless participants in a postharvest system are communicating openly with each other, they are quite likely to start out with very different perspectives on what product features make for success:

Growers: High yields of the highly valuable product;

Packhouse: Consistently high external quality, well-storing product that is cheap to sort, grade, pack, and store;

Distribution center manager: consistently high external quality product that has low levels of losses through the distribution phase and nil recalls;

Consumer: Safe and nutritious product that eats as well as it looks;

Marketer: consistently superior quality product that is valued by consumers, is produced without glut by growers to achieve “managed scarcity” and achieves consistently high prices.

Importance of Post-harvest technology

In the past, it has sometimes been argued that research to increase agricultural output is likely to be more cost-effective than research to increase efficiency in its use. No doubt, similar arguments have been advanced for forestry and fisheries. In the current climate of opinion, however, such views are open to serious criticism, even though there is not much quantitative evidence to discount them. The relentless increase of population pressure, the urgency of environmental conservation, the accelerating migration of people from the countryside to cities, and the declining rate of increase in yield potentials reflect only some of the considerations that call for greater efficiency in the exploitation of what is already available, whether from land, freshwater or the sea. For increasing productivity, scientists are trying to develop high yield potential and using biotechnology and other scientific tools followed by the development of a package for cultural practices. The problems extend from harvesting, through storage and processing to distribution, marketing, and final use and they have wide implications for poverty alleviation and sustainable production. Importance of post-harvest technology lies in the fact that it has the capability to meet food requirement of growing population by eliminating avoidable losses making more nutritive food items from low grade raw commodity by proper processing and fortification, diverting portion of food material being fed to livestock by way of processing and fortifying low grade food and organic wastes and by-products into nutritive animal feed. Post-harvest technology has the potential to create rural industries. In Bangladesh, where 80 percent of people live in the villages and 70 percent depend on agriculture have experienced that the process of industrialization has shifted the food, feed and fibre industries

to urban areas. It helps to generate more employment and income. Enhancement of employment opportunities of rural women. Through economic growth and social development, poverty will be alleviated.

On top of this, our world is:

- Home to nearly a billion hungry people (Brown, 2011);
- Needing to produce about 60% more food by 2050 to adequately support the projected increase in the human population by that time (Lipinski et al., 2013);
- Swept up in global system changes that threaten the sustainability of, let alone dramatic enhancements to, food production

The Basics of Post-harvest Technology

- Maintain quality (appearance, texture, flavor, and nutritive value)
- Protect food safety, and
- Reduce losses (both physical and in market value) between harvest and consumption.

Post-harvest technology stimulates agricultural production by

- Prevents post-harvest losses;
- Improves nutrition;
- Adds value to agricultural products;
- Opens new marketing opportunities; and
- Generates a new job.

Post-Harvest Losses

Post-harvest losses include all losses, starting from **grain/seed** harvesting before it is used for consumption or other purposes. In most developing countries agricultural productivity is lower compared to developed countries. In addition to the lower agricultural productivity, post-harvest losses of cereals and legumes range from 20–30% in most developing countries around the world.

Types of losses:

The first distinction in agro-food losses is that between quantity and quality, both of which significantly reduce the value.

Quantitative loss: Quantitative loss is a loss in terms of physical substance, meaning a reduction in weight and volume and can be assessed and measured. Quantitative losses occur due to spillage and scattering of grain, direct infestation by pests, birds, and mycotoxins, or mechanical breakages.

Qualitative loss: Quality criteria cover a wide range and are concerned both with external features, shape and size, and with odor and taste. The qualitative loss is concerned particularly with the food and reproductive value of products and requires a different kind of evaluation. Qualitative losses are mainly due to infestation by mold, mycotoxins, and mechanical breakages. The cultural factors that can influence diets and food habits must also be borne in mind. The cleanliness and healthy condition of a product are primary concerns for the market and

correspond to what is referred to as a "sound, legal and merchantable" product in commercial law. For example, if a trader takes a handful of grain from a sack, he can quickly see if it releases dust and works out if this is the result of insect infestation. Similarly, a bad smell can arouse suspicions that rodents have been at the grain, verifiable by the presence of rat or mouse droppings and hair. Many other objects can be mixed in with a foodstuff and reduce its value: bad grain, scraps of straw or other plant residues, soil, pebbles, bits of glass, etc. All such objects are hard to remove but some of them represent a greater risk of contamination than others: the soluble excreta of pests, oils, pesticides, pathogenic organisms spread by rodents and toxins from fungi and molds. It goes without saying that the presence of foreign bodies, which can distort the weight of a batch being sold, also affects the quality and thus the market value of a product.

Principal causes of quality losses

- Bird attack
- Rodent attack
- Insect attack
- Microorganisms infection
- Constraints like social, economic and political
- Economics
- Biochemical changes
- Leakage and waste
- Wrong moisture for storage
- Inadequate storage
- Poor transportation

Direct and indirect losses: Direct losses occur when the disappearance of a foodstuff is caused by leakage (for example, spillage from bags) or consumption by pests (insects, rodents, birds), whereas indirect losses occur when a reduction in quality leads to the consumer's refusal to purchase.

Weight loss: While weight loss is easy to observe and measure, it does not necessarily mean food loss, since it can result simply from a reduction in moisture content. Moisture loss during drying is therefore not a food loss. On the other hand, an abnormal increase in weight through moisture absorption following rainfall on stocks left in the open can cause serious damage resulting in a loss. Weight loss can be caused by leakage, during transport for example, if sacks have holes or are insecurely attached. It is often the result of prolonged infestation and consumption by insects, rodents, and birds or poor packaging. Weight loss from pests is not immediately apparent and may deceive an inexperienced purchaser. It can be checked by taking an equivalent amount of clean, healthy cereal, milling the two samples and weighing the flour from each. The poorer sample will produce less flour. This method can also be used to check whether the weight is correct, for it is easy to increase it by moistening the grain or adding foreign bodies such as pebbles, earth or waste material.

Principal causes of weight loss

- Premature harvest
- Poor maturation
- Poor threshing
- Insufficient drying
- Inadequate capital
- Professionalization
- Equipment
- Pesticides
- Packaging
- Transportation
- Organization

Commercial loss: Commercial loss is the translation of the various types of loss listed above into economic and monetary terms. Although the price of a foodstuff is usually based on weight, many other factors play a part. This applies especially to the qualitative elements emphasized above, starting with cleanliness and purity, which will be more sought after if supplies are abundant in the market-place. Reference to abundance brings us to the key economic factor of the supply-and-demand situation at a given moment. A producer's ability to take advantage of a time when the scarcity of a commodity pushes up the price is an element in good marketing management of his production, based on information and foresight. This assumes good organization, in which structural and not only market-situational factors are considered (for example, having enough storage facilities available and in good condition to be able to hold on to the harvest until the price rises) as well as keeping abreast of long-term developments, such as socio-cultural changes, which affect the future. Although this kind of market-oriented attitude depends on an individual's skills, it also has some collective aspects that deserve development. For the present, we would note that the ability to capitalize on a product depends on a number of technical and economic factors, in which the quality of the merchandise plays an increasingly important role but so also do the human qualities of the producer and hence, the training that readies him to take his place as an economic player in the life of his country.

Irreducible losses: While the loss of weight during drying is normal and measurable, there are other, said "irreducible" losses, which arise basically from respiration of the product and mechanical rubbing of grain against itself, as well as the breakage inevitable with certain machines. It should therefore always be remembered that losses, whether pre-harvest or post-harvest (i.e. in production, distribution, storage or marketing) cannot be materially reduced to zero and that they must be compensated for through extra production. The production increase rate must be progressively higher than that of losses, if such compensation is to be adequate, so that compensation for a 20 percent loss will require 25 percent more production, for a 40 percent loss, 66 percent more and for a 60 percent loss, 150 percent more.

It should be noted that we shall not consider losses occurring during the production period and caused by various crop pests (insects, weeds, disease), even though they have a major influence on food preservation conditions and account in part for the nature and size of post-harvest losses. After describing direct and indirect losses, we shall thus look at weight loss, then quality loss, food loss, seed viability loss and commercial loss. We should not forget the existence of moisture content and the difference between damage and loss.

Moisture content: In biochemical terms, organic products are composed of dry matter and water. The moisture content is the amount of free water within a given product and is expressed either as a decimal proportion or a percentage. For example, with cereals, a 13 percent moisture content is considered a guarantee of satisfactory grain preservation. In agriculture, moisture content or humidity rate is usually indicated as a proportion of the moist product; i.e. the moisture content is the proportion of the weight of moisture to the total weight of dry matter and moisture.

Damage: Damage is a clear deterioration in the product, e.g. broken or pitted grain, which affects more its quality than its quantity and can in the long-term result in a definite loss. Both damage and loss should be quantified in terms of weight and cost.

Food loss: Food loss refers to total modification or decrease of food quantity or quality which makes it unfit for human consumption.

Foodstuff: Products, in the present case crops, edible by human beings; more specifically, the part fit for human consumption. In tropical countries, 75 percent of basic food comes from cereals and pulses.

Grains and seeds: Cereals, pulses and oilseeds grown in most climates and latitudes for human consumption. The main cereals are wheat, maize, rice, barley, sorghum, millet, oats and rye; pulses cover the various species of pea, bean, broad bean and lentil; and oilseeds cover soya, groundnut, sesame, rapeseed and sunflower.

Factors for post-harvest loss

There are different factors associated with different forms and extents of post-harvest losses along the grain supply chain (Figure 2). Despite the ever-increasing sophistication and integration of some parts of the food supply system, overall levels of postharvest food wastage are of the order of 30%. When assessed on a calorific basis, losses of the cereals figure most prominently, at 53% of the total wastage.

Cereals and legumes are usually harvested within a short harvest period. Harvesting is usually performed manually using a sickle or knife by smallholder farmers. Harvesting needs to be performed at the proper time, possibly just after the crops are mature with grain moisture contents between 20–28% for maize and rice, and 14–18% for cowpeas, to minimize harvesting losses. Crops have a higher moisture content when harvested too early, which either will require longer drying times or could provide favorable growing conditions for mold, resulting in increased costs or losses. Also, if harvesting is done during rain, the increased grain moisture content could result in unexpected grain germination. If the crops are harvested too late, they are exposed longer in the

field and have more chance of being attacked by birds, insects, and mold. Furthermore, field drying of the grain could result in losses due to shattering of grain during harvesting.

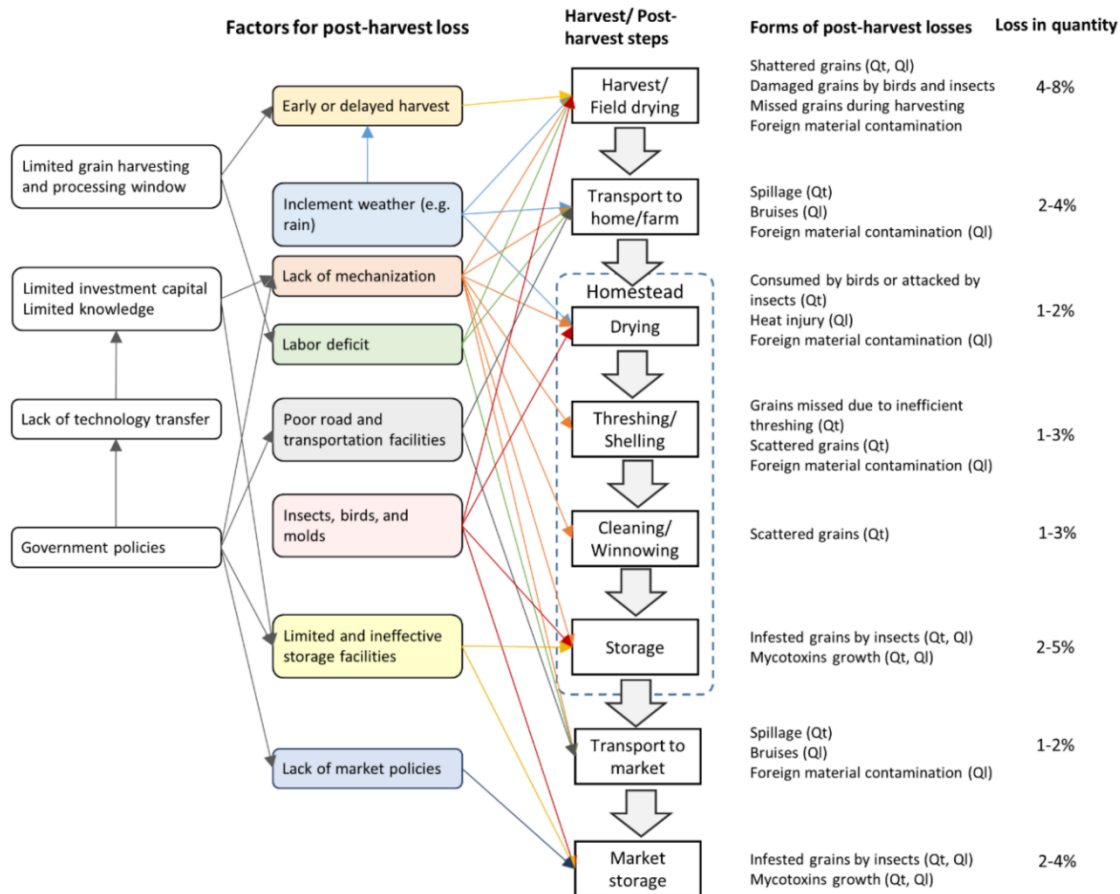


Figure 2. Factors for losses during different post-harvest steps of the grain supply chain.

Qt—Quantitative loss, Ql—Qualitative loss.

Smallholder farmers transport the harvested grain to the homestead by carrying them or using bicycle or bullock carts. Some farmers hire trucks to haul their grains. Losses due to grain spillage and bruises can occur during transportation. Foreign materials could also contaminate the grains if not properly secured during transportation. Grain is usually field-dried or naturally dried in mats or cribs in a homestead yard with potential losses during drying by infestation from birds or insects, or heat injury. Depending on the regions, the grain is then stored with either cobs or stalks intact in cribs or threshed/shelled, cleaned, and stored in different storage structures. Some farmers de-husk and shell the grain in the field, while others do it in their homes. Grain is normally stored in jute bags, propylene sacks, or traditional cribs for a few months. In some cases, maize is stored for almost seven months until the next harvest is available. The market price also tends to increase within

six months of storage. Storage losses, mainly occurring due to insects and mycotoxins, are considered to be the highest among the post-harvest steps of grain produced by smallholder farmers and could occur in farm as well as market storage. Most of the grain is stored to be consumed by family members, whereas some grain is usually stored for a few months and then sold to the market depending on the grain quality after storage. The grain is then transported to the market where it might be stored further before being purchased and used by other people.

Food Grain Storage

The challenge of feeding over growing human population cannot be met with the increase food production alone. During the last two-decade production of food has been increased significantly in order to make further progress it requires inputs like seed, fertilizer, pesticide and advanced post-harvest technology.

The losses during crops and post-harvest handling, processing, storage, and distribution systems vary between 20-60% of food grain are lost during post-harvest operation. If these losses are minimized, the shortage of food in many countries can probably be eliminated. Food grains are stored for later use as seed, reserved food or buffer stocks. Insects, microorganisms and rodents not only consume the edible parts of growing crops and stored grains but also lead to the deterioration in quality in quality. Hence, integrated approach for the control of pest is essential for maintaining quality during growth, production as well as at post-harvest handling and storage periods.

Factors Affecting Grain Storage Practices

Grain is usually stored for several months after harvest, which is much longer than other grain post-harvest steps. Also, the grain is minimally monitored during storage. Thus, proper grain storage conditions are needed to minimize grain losses. Factors that play a crucial role in storage losses can be classified as physical, biological, and socioeconomic.

Physical Factors—Temperature, Moisture, and Oxygen

Physical factors such as oxygen, moisture, relative humidity, and temperature have a major impact on the storability of grain. Physical factors influence the conditions for insect multiplication and mold growth during grain storage, which eventually affects the storability of the grain.

- Temperatures in the range of 25 to 35° C create favorable conditions for the rapid growth of most storage insects. Under these conditions, insect reproduction accelerates, which increases grain consumption and generates more heat, maintaining an optimal environment for insects. However, at temperatures lower than 13° C or higher than 40°C, insects tend to lower their activity, migrate, or eventually die. Also, mold growth was observed in storage conditions with a temperature between 20° C and 40° C, with optimal growth for most molds occurring between 25°C and 30°C.

At the appropriate temperature and moisture content and with the availability of food sources (grain in this case), mold spores settle on a surface and grow rapidly. In addition, temperature gradients also promote moisture collection at specific locations in the storage system, which provides favorable conditions for mold growth.

When cereals are stored in a silo or warehouse, the temperature at the center of the grain volume remains relatively like that during harvest, and the grain farthest from the center that is in contact with the storage walls has temperature variations based on the ambient air temperatures. Thus, for grain stored at a high moisture content and high relative humidity, when the outside temperature decreases, the walls cool faster, which causes condensation and develops wet spots, facilitating mold growth.

- Mold and insects require moisture for their growth. Mold proliferates at a relative humidity (RH) above 70%, and thus grain needs to be stored at lower RH, preferably below 60%, especially if stored for extended periods. The equilibrium moisture content corresponding to this RH for most cereals is below 13% and for legumes is below 15%, which is preferable for long-term grain storage. Higher moisture content has shown to be detrimental to grain in terms of dry matter loss and quality. Lowering the RH to 9% during storage has been shown to increase insect mortality up to 98% within 24 hours. Furthermore, available water is used by insects as it is one of the main requirements for their survival.
- Higher moisture and oxygen availability increase the grain respiration rate and generates heat, carbon dioxide, and enzymes, which break down the starch, proteins, and lipids in grain. Insects utilize the available oxygen during metabolic activities and raise the carbon dioxide concentrations within the hermetic storage system through respiration. The insects' feeding activity drops progressively in proportion to the varying gas concentrations and nearly stops at 3–6% (v/v) oxygen and 15–18% (v/v) carbon dioxide. However, for near-complete control and to achieve almost 100% insect mortality, the O₂ concentration should drop to 1–3% or CO₂ should rise to 35%.

Biological Factors—Insect and Rodent Activity, and Mold Growth during Grain Storage

- **Insect/Pest and Rodent Activity**

Geography and climatic conditions affect the probability and severity of grain infestation by insects and pests. Pest infestations can occur in the field as well as during storage. In most storage practices, insect growth and mold formation take place within the system. However, depending upon the storage types and conditions, their active period differs. Insects mainly damage the stored products by direct feeding. These insects feed on the endosperm, resulting in a loss of weight and quality of grain as well as grain germ, causing poor seed germination. Grain infested by insects loses value for consumption or planting. Grain borers, such as the large grain borer (LGB) (*Prostephanus truncatus*), and grain weevils (*Sitophilus granarius*), are the main pests responsible for grain storage losses. The maize weevil (*Sitophilus zeamais*) is the main insect responsible for the deterioration of stored maize, sorghum, and other grain in the tropics. As these attacks intact grain, they are also labeled as primary pests, whereas secondary pests such as the red flour beetle (*Tribolium castaneum*) attack already infested grain. Birds and rodents can infest the grain while in the field before harvesting, whereas rodents could also be a problem during storage.

- **Mold Formation and Growth**

Mold formation in stored grain can produce different mycotoxins, which are toxic chemicals unsuitable for human consumption. In addition, mold generates other problems besides mycotoxins, such as dry matter loss, odor, and a loss of nutritional value. Thus, the presence of active mold in stored grain can greatly limit grain usage due to quality loss and mycotoxin formation. Mycotoxins, such as aflatoxins, ochratoxins, trichothecenes, zearalenone, and fumonisins, developed mainly from fungi, such as *Fusarium*, *Aspergillus*, and *Penicillium*, are common in grain in most countries. Mold can develop on the crop in the field as field fungi, as well as during storage as storage fungi, thus creating two bases of mycotoxins owing to mold formation. Mold growth during grain storage is dependent on grain moisture content, temperature, gas composition, relative humidity (RH), and fungus contamination during field harvest and storage. Reducing the grain moisture content to less than 13% and relative humidity to less than 60% during storage is crucial to limit mold activity. Field-based fungi require a much higher moisture content and thus rarely develop under storage conditions because of limited moisture and water activity. However, storage fungi such as *Aspergillus* sp., which produces aflatoxins, could develop well at RH between 70% and 90%, which corresponds to an equilibrium moisture content higher than 16% for most grain. Thus, mold formation needs to be properly addressed during storage to minimize grain losses.

- **Socioeconomic Factors**

The adoption of different storage structures also depends on socioeconomic factors, such as the farmers' family size, land holding size, required grain storage duration, off-farm income, road accessibility, the market price of grain, and grain safety during storage. Usually, large families have a greater demand for grain consumption and, thus, could more readily adopt better grain storage practices. Smallholder farmers with a relatively larger land holding could afford new storage technologies compared to those with a small farm area. Farmers having off-farm income have more financial resources at their disposal to invest in effective storage technologies. Farmers requiring grain to be stored for a longer duration for a higher selling price usually prefer improved storage technologies for grain storage compared to those stored for a shorter time. The higher market price of the good-quality grain after a few months of storage provides justification for farmers to spend more to store their grain for minimal loss or to preserve quantity and quality. Farmers preferring the security of their grain from potential theft or effects of adverse climatic conditions tend to store their grain in portable containers inside their houses.

Table 1. Comparison between properties of cereals and roots and tubers regarding their storage capacity
(Source: FAO, 1984, quoted by Knoth, J., 1993)

Non-perishable food crops	Perishable food crops
Harvest mainly seasonal, need for storage of long duration	Possibility of permanent or semi-permanent production, needs for short-term storage
Preliminary treatment (except threshing) of the crop before storage exceptional	Processing in dried products as an alternative of the shortage of fresh products
Products with low level of moisture content (10-15 percent or even less)	Products with high level of moisture in general between 50-80 percent
Small "fruits" of less than 1 g	Voluminous and heavy fruits from 5 g to 5 kg or even more
Respiratory activity very low of the stored product, heat limited	High or even very high respiratory activity of stored products inducing a heat emission in particular in tropical climates
Hard tissues, good protection against injuries	Soft tissues, highly vulnerable
Good natural disposition for storage even for several years	Products easily perishable, natural disposition for storage between some weeks up to several months (strong influence of the varieties)
Losses during storage mainly due to exogenous factors (moisture, insects or rodents)	Losses due partly to endogenous factors (respiration, transpiration, germination) and partly to exogenous factors (rot, insects)

Table 2. Duration of safe storage of food grain at different moisture content and temperature

Moisture content (%)	Safe storage period (days) at different temperature (°C)					
	5	10	15	20	25	30
13				180	115	90
14			160	100	50	30
15			100	50	30	15
16		130	50	30	20	8
17		65	35	22	12	5
18	130	40	25	17	8	2
19	70	30	17	12	5	0
20	45	22	15	8		
21	30	17	11	7		
22	23	13	8	6		
23	17	10	7	5		
24	13	8	6	4		
25	10	8	4	3		

The post-harvest processing industry incorporates three major components

1. Primary processing, i.e., cleaning, drying, storage, packaging, etc. Raw materials are purified by removal of foreign matter and immature grain and are then prepared for grading and secondary processing.
2. The secondary processing stage mostly involves de-husking, de-hulling, splitting, sorting and polishing of grains, i.e., processing of the raw material into products suitable for food uses or consumption after cooking, roasting, frying, etc.
3. Tertiary processing, which involves further processing of grains into useful food products, i.e., value addition and creation of ready-to-eat forms.

The terms ‘commodity system’, ‘value chain’ and ‘supply chain’ are used interchangeably to include production, collection, processing, wholesaling, and retailing as well as support functions, such as input supply, financial services, transport, packaging, and advertising. A systematic analysis of each commodity’s production, postharvest handling, and marketing system is the logical first step in identifying an appropriate strategy for reducing postharvest losses. While value chain analysis typically considers five major components that are common for all products (production, collection, processing, marketing, and consumption), commodity systems assessment includes these five components.

Commodity system

The representative commodity system includes more than just a farm-level production activity. Consideration of farm-level costs and returns would be sufficient to evaluate the efficiency and competitiveness of production for home consumption.

Value chain

the process or activities by which a company adds value to an article, including production, marketing, and the provision of after-sales service.

Value addition

1. the amount by which the value of an article is increased at each stage of its production, exclusive of initial costs.
2. the addition of features to a basic line or model for which the buyer is prepared to pay extra.

Supply chain

the sequence of processes involved in the production and distribution of a commodity.

Grain quality

Grain quality is a term that refers to the quality of grain. However, what constitutes quality depends on the use of the grain.

For instance in ethanol production, the chemical composition of grain such as starch contents is important, in food and feed manufacturing, properties such as protein, oil, and sugar are significance, in milling industry soundness is the most important factor to consider and for seed producer, the high germination percentage (viability of seed) and seed dormancy is the important feature to consider, for consumers the properties like color and flavor will be important.

Properties of grain quality

The properties of grain quality can be summarized into ten main factors

- Uniform moisture contents
- High test weight
- No foreign material
- Low percentage of discolored, broken and damaged kernels
- Low breakability
- High milling quality
- High protein and oil content
- High viability
- No aflatoxin (mycotoxin)
- No presence of insects and molds.

Research achievements and needs

Future postharvest research needs to build on existing knowledge, and be adaptive, applied, and suitable for small-scale users

1. inadequate marketing systems;
2. inadequate transportation modes;
3. unavailability of needed materials, tools, and/or equipment;
4. lack of information; and
5. governmental regulations and legislation.

Capacity building in postharvest research is an obvious need in many developing countries and can be achieved via internships, faculty exchanges, human resource development for staff in university laboratories and research centers, laboratory upgrades, improved access to web-based information, and mentoring.

Although there are a few researchers in each developing country who carry out some postharvest research, there tends to be very little coordination among the postharvest researchers within each country or among countries within each region.

Also lacking is interdisciplinary collaboration among production agronomists, plant pathologists, entomologists, marketing economists, engineers, food technologist, consumer scientists, and others who may be involved in various aspects of the production and marketing systems. Such cooperation and collaboration are essential to establishing effective research and extension programs.

Suggest Reading

- Post Harvest Technology of Cereals, Pulses and Oilseeds. 3rd Edition. 2017. Author: Amalendu Chakraverty
- Postharvest Handling A Systems Approach. • 3rd Edition • 2014. Edited by: Wojciech J. Florkowski, Robert L. Shewfelt, Stanley E. Prussia
- Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices. 2003. Authors: Amalendu Chakraverty, Arun S. Mujumdar, Hosahalli S. Ramaswamy
- Postharvest Technology: Cereals, Pulses, Fruits and Vegetables. 2001. Authors: Amalendu Chakraverty and R. Paul Singh

POST-HARVEST TECHNOLOGY OF GRAINS AND CEREAL

Introduction

- In botany, grains and cereals are synonymous with caryopses, the **fruits of the grass family**.
- All three native grains are broad-leaved plants rather than grasses such as **corn, rice, and wheat**.
- Cereal crops are all members of the grass family.
- Cereal grains contain much starch, a carbohydrate that provides dietary energy.

Grading of Cereal

Grain quality

- **Grain quality** is a term that refers to the **quality of grain**. However, what constitutes quality depends on the use of the grain.
- For instance in ethanol production, the chemical composition of grain such as **starch contents** is important, in food and feed manufacturing, properties such as protein, oil and sugar are significance, in milling industry soundness is the most important factor to consider and for seed producer, **the high germination percentage** (viability of seed) and **seed dormancy** is the important feature to consider, for consumers the properties like **color and flavor** will be important.

Properties of grain quality

The properties of grain quality can be summarized into ten main factors

- Uniform moisture contents
- High test weight
- No foreign material
- Low percentage of discolored, broken and damaged kernels
- Low breakability
- High milling quality
- High protein and oil content
- High viability
- No aflatoxin (mycotoxin)
- No presence of insects and molds.

RICE POST HARVEST TECHNOLOGY

Globally rice ranks second to wheat in terms of area harvested, but in terms of importance as a food, it provides more calories per hectare than any other cereal crop. A hectare of rice can sustain 5.7 persons for a year compared to 5.3 for maize and 4.1 for wheat. In Asian diets, milled rice provides 40-80 percent of the calories and at least 40 percent of the protein. Rice has one of the most nutritious protein contents (100 percent digestible) among the cereals. Besides its importance as food, it provides employment to the largest sector of the rural population.

The calorie value of rice compared to other cereals is given below:

Cereals	Calorie value (per 100g of edible portion)					
	CHO(g)	Protein(g)	Fat(g)	Calorie (k cal)	Ca(mg)	Fe(mg)
Rice	77-79	6.4-8.5	0.4-1.5	345-349	9-10	3-4
Wheat	69-74	11.0-12.1	0.9-1.7	341-348	23-48	3-12
Maize	66	11.1	3.6	342	10	2
Millets	61-73	10.4-12.3	1.9-5.0	331-361	25-42	5-13

Source: Krishi by H. Kabir

The importance of post-production technology of rice has increased due to the increased yields from the high yielding varieties. Losses had been small in absolute terms expanded proportionately with increased farm-level yields. The problem of determining the magnitude and source of losses in the post-harvest sequence of operations is important and complex. All post-production operations such as handling, threshing, drying, and storage are inter-dependent. A close relationship between performance at the processing level and operations at farm level has been reported. When rice is improperly threshed, dried and cleaned at the farm level, it is impossible to achieve high milling efficiency at the processing plant. Rice grain quality can be affected by variety, environment, and processing. To improve the quality or quantity of processed rice, there is a need to consider the entire post-production operation as a system. Environmental and handling conditions during ripening, harvest, postharvest, and processing can enhance or impair grain quality. Processing also increases the price of rice. Yields of head rice vary depending on many factors such as variety, grain type, cultural practice, drying, storing parboiling and milling conditions.

To minimize post-harvest losses, the following measures should be followed.

Harvesting

- For paddy, harvesting refers to the cutting and gathering of panicles attached to the stalks.
- Harvesting at the right time and in the right way maximizes grain yield and minimizes grain losses and quality deterioration.
- Once the plants have reached full growth (approximately three months after planting) and the grains begin to ripen-the tops begin to droop, and the stem yellows-the water is drained from the fields.
- As the fields dry, the grains ripen further, and harvesting is commenced.

Stage of harvest:

Many factors must be considered to obtain optimum rice harvest.

- The grain must be mature, high in quality and have proper moisture content.
 - Field should be sufficiently dry to support harvesting and transport.
 - Timely harvesting ensures good grain quality, high market value and improved consumer acceptance.
- Harvesting before or after that period resulted in an increase of broken grains.

Two main observations used to determine the correct harvest time for rice grains are:

Moisture content: Grain moisture content is ideally between 18 and 22%w.b. (wet basis). Grains should be firm but not crumbly when pressed between the teeth.

Ripe grains per panicle: The crop should be harvested when 80-85% of the grains on the field have changed color from green to matured yellow.

Maturity may be hastened by 3-4 days by spraying 20 % NaCl a week before harvest to escape monsoon rains.

Harvesting methods:

Depending on the size of the operation and the amount of mechanization, rice is either harvested by hand or machine. When harvesting the rice by sickle or knife, cut the rice straw 4-5 cm from the ground level and do not leave much bigger portion of its standing. Standing straws and straw stumps still remaining in the field can have stem-borer worms and adults to complete its life cycle. Always destroy the straw by cutting as low as possible to the ground and up-root and destroy the straw stumps and incorporate it into the soil by hoeing soon after the harvest and ready for the next season.

- **Manual harvesting and machine threshing**
Rice is manually threshed, then cleaned with a machine thresher.
- **Machine reaping and machine threshing**
A reaper cuts and lays the crop in a line. Threshing and cleaning can then be performed manually or by machine.
- **Combine harvesting**
The combine harvester combines all operations from paddy harvesting to rice extraction - cutting, handling, threshing and cleaning.

Post-Harvest Technologies**Threshing**

Threshing is the physical process of separating the grains from the rice straw and the panicles.

- To maintain the high quality of the harvested grains, it should be threshed immediately after harvesting. Rice straws and panicles harvested that are wet from over-night rains or by the morning dew must be field-dried before threshing, often morning-half of the day is committed to harvesting and afternoon-half of the day is to do all the threshing.

- Avoid field drying and stacking for several days as it affects grain quality due to over drying. Stacked grains of high moisture content results in discoloration or yellowing.
- Use wide canvass or plastic sheets with the edges raised to catch all the grains being threshed through the beating-action.

If not handled properly results in broken /damaged grains and mixing with other foreign matter including sand, stones and other rice.

Threshing methods for rice vary from country to country. Threshing can be done manually or mechanically. Threshing losses vary with the thresher used.

Manual threshing

- The manual methods of threshing are treading by feet, flail method, and beating stalks against tubs, boards or racks.
- Threshing can be done by trampling using bullocks, rubbing with bare human feet (in hills) or lifting the bundles and striking them on the raised wooden platform.
- Pedal threshers are also used.
- Freshly threshed rice must be dried well in the sun.

Machine threshing

- Mechanical threshing removes rice grains from the rice plant, speeds up threshing (thus reducing losses), and reduces labor requirements.
- Power driven stationary threshers are also used.

Problems of threshing

Manually (manpower)	Mechanically (use of combine harvesters)
• Method is time consuming, laborious and output is quite low	• Method is efficient, high maintenance cost, high output
• Contamination of paddy with sand, stone, immature grain and other foreign materials is high	• When used in fields with well dried grains, many of the grains fall or are broken
• Loss of grain leading to reduction in overall output	• Most appropriate in good leveling and water control farm

Winnowing

Threshed grains are winnowed. In Bangladesh, it is usually done by winnower- Kula, bower or by fan. BRRI has developed a winnower named BRRI power winnower which can winnow 12 monds grain/hr. It is very suitable in case of seed crop.

Good winnowing practice involves:

- use of plastic sheets /traditional mats e.g. tarpaulin
- a clean environment
- the operator should not re-contaminate the winnowed grains with dust, sand etc.

Dry the paddy soon after threshing both in the outdoor and the in-door sheds to prevent grains from fermentation if the moisture remains in a heap or bag of grains for too long.

Drying

Drying is the process that reduces the moisture content of the rice paddy down to a safe-level where rice can be properly milled and, importantly, put away safely for storage. Once dried, the rice grain, now called rough rice, is ready for processing. Drying is the most critical operation after harvesting a rice crop. This is done to reduce the paddy moisture content to between 12 and about 14% depending on the time of storage. Any delay in the drying process, incomplete drying or ineffective drying will reduce the grain quality and result in post-harvest losses. Improper drying, especially during the wet season, contributes to losses due to rotting and down-grading of the quality of milled rice as characterized by a high broken percentage, discoloration and mould infestation. Proper drying results in increased storage life of the grains, prevention of deterioration in quality, reduction of biological respiration that leads to quality loss of grains, and optimum milling recover.

Methods of drying

- Sun drying
- Mechanical drying
- Chemical drying

Sun Drying

Sun drying is a traditional method of drying the paddy grains. Sun drying is the most economical method of drying grains. Grains are spread on drying surfaces such as concrete pavement, mats, plastic sheets and even on fields with the layer of about 4-5 cm depth to dry naturally.

Process of sun drying

- Turn-over the paddy every 30 minutes using a garden rake and by using hand and foot, tenderly spreading the grains as they dry.
- Slow-drying of the rice paddy will prevent cracking; and by contrast, quick and fast drying will cause the grains to crack and will result in lot of broken grains when milled.
- Ensure that the surface temperature of rice paddy being dried does not rise above 36°C or must be kept lower than 36°C. High grains temperature will destroy the grain embryo if one is to keep the grains for seeds.
- In a stored grain, both in sacks or canvass bags with inadequate drying, the paddy rice temperature can suddenly rise above 36°C, this may mean there is a high moisture content and the rice paddy may

germinate under such condition. However, the germination will be short-lived as all the seeds that sprout will be smothered within the storage sack or canvass.

- When putting the high moisture paddy into the bags, keep the mouth of bags open to all the air movement and the release the heat and dampness from bag.

Further Explanation:

- Slow drying is preferable to avoid the cracking of rice grain.
- Below are the rice embryo's figures. Baby leaf and root already exist in it. The enzyme activity to use starch of endosperm loses by high temperature over 36°C.
- Don't mix the paddy with 5%-different moisture content because it causes the production of fermentation and mold. Also, it is difficult to make the moisture of paddy evenly before milling.
- Equilibrium moisture content of paddy is related with air temperature and relative humidity.
- When drying paddies under the sun, it is necessary to spread them and turnover continuously and evenly, maintaining a certain thickness (4–5 cm thick), and it is important to spread them evenly. It depends on the weather, but it is very important that the crop temperature doesn't rise to or above 36°C (roughly the human body temperature). For this purpose, though it depends on weather, it is necessary to watch crop temperature and to repeatedly turn paddies upside down (every 20–30 minutes). By doing so, paddy can be dried evenly without generating cracked or damaged rice.

Advantages of sun drying:

1. No fuel or mechanical energy is required
2. Operation is very simple
3. Viability, germination, baking quality are fully preserved
4. Microbial activity and insect/pest infestation are reduced
5. Labor oriented
6. No pollution

Disadvantages of sun drying:

1. Completely dependent on weather.
2. Not possible round the year and round the clock.
3. Excessive losses occur due to shattering, birds, rodents etc.
4. The entering process is unhygienic
5. Unsuitable for handling of large quantity of grain within a short period of harvest.

Mechanical Drying

- Mechanical drying process means drying the grains by ventilating natural or heated air through the grain mass to get it evaporated the moisture from it.
- Mechanical dryers are more reliable since drying could be done anytime of the year.

According to the mode of heat transfer, mechanical drying methods can be divided into:

- **Conduction drying**

When the heat for drying is transferred to the wet solid mainly by conduction through a solid surface (usually metallic) the phenomenon is known as conduction or contact drying. In this method, conduction is the principle mode of heat transfer and the vaporized moisture is removed independently of the heating media.

- **Convection drying**

In convection drying, the drying agent (hot gases) in contact with the wet solid is used to supply heat carry away the vaporized moisture and the heat is transferred to the wet solid mainly by convection.

- **Radiation drying**

Radiation drying is based on the absorption of radiant energy of the sun and its transformation into heat energy by the grain. Sun drying is an example of radiation drying.

Chemical Drying

Chemical drying method involves the spraying of common salt solution with specific gravity of 1.1 to 1.2 on the ears of the mature paddy crop. This treatment reduces the moisture content from 29% to 14.5% after four days. The common salt absorbs moisture, from paddy but it cannot penetrate into the endosperm through the husk layer. This is a unique property of the paddy, which has rendered the application of common salt preservation possible.

Advantages of chemical drying

- It not only dries but also reduces the damages to fungal, microbial and enzymatic activities and heat of respiration.
- It does not affect the viability of the grain.
- The milling quality of paddy is satisfactory.
- Loss of dry matter is negligible.
- It does not affect the quality of rice bran.

Disadvantages of chemical drying

- The moisture may be retained on the husk due to the presence of sodium chloride. The useful life of gunny will be shortened.
- The color of husk changes to dark yellow.
- The common salt treated 'paddy requires an additional spraying subsequently. Economy of the process has yet to be established.

Cleaning

Cleaning is the process to remove rice straw chaff, foreign matters and immature/empty grains within paddy after threshing and drying.

High percentage of chaff, foreign matters include the soil piece, sand, small stones, metal debris, plastic or paper pieces, twig and branches, wood piece, weed seed, other grains, chemical and poisonous matters, etc.,

will unnecessarily increase the number of sack of rice and weight of paddy, which may cost the grower avoidable transport fees and milling fees paid the mill operator; and for the rice mill operator the cost of wear-and-tear and spoilage to his machine.

The importance of cleaning is as follows:

- To remove foreign matter, broken and immature grains to gain high milling recovery rate [to reduce broken rice amount].
- To increase the milling efficiency [to reduce fuel consumption].
- To decrease the damage of machine.
- To decrease running cost due to less wear of consumable parts.
- To increase more than 5% of mechanical efficiency and energy consumption if percentage of foreign matter, broken and immature grains is less than 1%.
- To decrease post-harvest loss.

Further explanation

- Prevent broken rice. 5% broken rice decrease 10% on milling recovery.
- The immature grains are classified into impurity. Immature grains decrease the milling recovery rate and the mechanical efficiency of the rice milling unit and is the cause of broken rice grains.

Use winnowing tray/ basket and mechanical cleaners such as manual winnower, oscillating sieves and aspirator. Small stone and sand that cannot be removed by winnowing can be removed hand picking.

Parboiling-partly cook (food) by boiling.

Parboiling is a hydrothermal treatment procedure in which the paddy is soaked in warm or cold water followed by steaming and drying before milling. Parboiling of paddy is common in many rice-producing countries, including Bangladesh. Over 90% of the rice in Bangladesh is parboiled before milling. It affects the milling, storage, cooking, nutritional quality and ultimately consumer preference. In the parboiling process, rough rice is soaked, steamed and re-dried before milling.

Parboiling *gelatinizes the starch within the rice grain, thus causing swelling and fusion of starch within the kernel.

*Starch gelatinization is a process of breaking down the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to engage more water. This irreversibly dissolves the starch granule in water.

The process of parboiling is carried out in three main steps

- Soaking
- Steaming
- Drying

Soaking, steaming and drying have a great influence on the final characteristics and quality of parboiled rice.

Soaking of paddy is done at or below the gelatinization temperature. The lower the temperature, the slower the process of soaking and vice versa.

a. Soaking

Paddy, being a hygroscopic material, can absorb water both as a vapor and as a liquid, and thereby swells. The process of simultaneous water absorption and swelling is known as soaking, steeping or imbibition.

Two conditions appear to be necessary for soaking:

- 1) A certain affinity must exist between absorbent and adsorbate, and
- 2) A diffusion pressure gradient must exist between the water vapor of the absorbent and that of the material to be imbibed.

b. Steaming

The use of steam for gelatinizing the starch in the paddy grain is preferable to other methods of heating because it does not remove moisture from the soaked paddy, rather it adds moisture by condensation, which increases the total moisture content of the grain. The other advantages of steam are that its high heat content is applied at constant temperature, it is sterile, and it can be used to produce power before it heats the paddy.

During steaming, the following points should be considered:

- Whether the steam is saturated or superheated
- The pressure of the steam, which determines the temperature at which heat is transmitted, and
- The steaming time, which determines the total heat supplied to the paddy to cause the gelatinized of the starch

The total amount of heat applied to the paddy is equal to the heat provided by the soaking and steeping water plus the heat derived from the consideration of steam during the steaming operation.

c. Drying

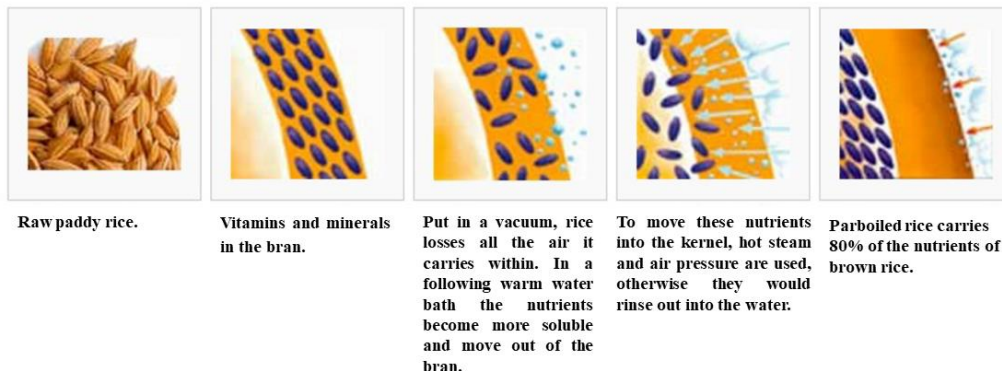
The parboiled paddy is required to be dried to moisture of 14-16 per cent to obtain the desirable milling and storing properties. In Indian subcontinent, drying is generally carried out on large paved yards in the rice mills. The paddy is dried to a moisture of about 18-20 per cent, then heaped, tempered for few hours, and then again dried for 1-2 hours to bring down the moisture to 14-16 percent.

The drying is also carried out in mechanical driers in some mills with hot air. The most important aspect in drying is that the process should be carried in two stages. If the drying is continued in one stage below moisture of 18 per cent there is considerable amount of breakage. However, if it is conditioned at that level and again dried to 14-16 percent moisture, the breakage is considerable reduced.

Parboiling has the following advantages:

- To reduce breakage during milling.
- To improve the nutrient content of the milled rice.
- To change the cooking qualities (taste, appearance, aroma, texture etc.) of the rice.
- Easier dehulling.

- Harder grain, which are less vulnerable to insect attack during storage.
- Cooked parboiled rice is less sticky than freshly harvested raw rice.



Disadvantages of parboiling are

- Parboiled rice becomes rancid during storage.
- Longer cooking time is required.
- Additional cost is involved in the drying operation following parboiling.
- Parboiled rice requires more energy to achieve the same degree of milling.

A few traditional methods of the traditional pre-milling treatments to improve the milling, nutritional, cooking and keeping qualities are:

Atapa

This treatment originated in Bengal. The paddy is soaked in water at room temperature for 24 hours and then dried in the sun (hence the name atapa or sun dried). The dried paddy is then milled by traditional methods. The relative breakage of rice more in this process.

Balam

This treatment also originated in Bengal. It is slightly better than atapa. Here the paddy is sprinkled, remove.

Josh

This treatment was developed in Larkhana, Pakistan. Large earthen pots filled with paddy and water is placed on 15 cm layer of hull, which is used as fuel. The pots remain on the fire overnight. The next day the water is drained, and the paddy is placed on shallow iron pans and heated over fire for one hour. The paddy is then dried in sun.

Sela

This treatment was originated in Saharanpur, India. Paddy is soaked in water at room temperature for 24-48 hours and then gently roasted in hot sand (80-90°C). The roasted paddy is then further dried in sun and milled.

Siddha

This treatment originated in Bengal. Paddy is soaked in water at room temperature for 20 hours, and then boiled for few minutes. It is finally dried in sun. In this method, rice from over-soaked paddy become coarse in appearance, and rice from over-dried paddy shows poor milling quality.

Methods of parboiling

Parboiling is the latest treatment, which improves the quality of rice. The traditional parboiling process in India is carried out in different ways.

The methods of parboiling may be classified into three groups (the name in parenthesis indicates where the method was developed or is being studied):

(1) Traditional methods: The traditional process consists of soaking in water at room temperature for 24-48 hours or more, steaming in kettle, and drying in the sun.

a) Single boiling: Single boiling method involves soaking the unhulled rice in water at room temperature for 24-72 hours followed by open steaming for 20-30 minutes using iron kettles and then sun drying.

b) Double boiling: In double steaming method, the unhusked rice is first steamed to raise its temperature 45-50°C and then soaked in cold water for 24-36 hrs. After soaking, it is steamed second time for 20-30 minutes followed by sun drying. Sometimes the soak water itself is heated to about 50°C before the raw paddy is dumped into it. In this case, the first steaming on the raw paddy is not required.

(2) Modern methods being used

(a) CFTRI method (Indian) - Central Food Technological Research Institute

CFTRI method of parboiling

Parboiling tank is filled with clean water and heated to about 85°C.

Paddy is dumped into hot water in tank for soaking. The temperature of paddy-water mixture comes down to 70°C which is maintained for 3-3.5 h.

After soaking, water is drained from tank and then exposed to steam at a pressure of 4 kg/cm² until husk starts splitting.

Steamed paddy is dried in multiple passes.

During parboiling, the water requirement is about 1.25 times the weight of paddy and requirement of steam is about 200 kg/ton of paddy.

(b) Jadavpur University method (Indian)

(c) Converted process (American)

(d) Malek process (American)

(e) Avorio process (Italian)

- (f) Cristallow process (Italian)
- (g) Fernandesc process (Surinam)
- (3) Modern methods under study
 - (a) Brine solution method (Indian)
 - (b) Kisan continuous method (Indian)
 - (c) Pressure parboiling method (Indian)
 - (d) RPEC method (Indian).
 - (e) Sodium chromate method (Indian)
 - (f) Parboiling with heated sand method (Philippines)

Milling

Rice milling involves the removal of hulls and bran from rough rice to produce polished rice

- Milling is the process wherein the rice grain is transformed into a form suitable for human consumption, therefore, has to be done with utmost care to prevent breakage of the kernel and improve the recovery.
- Brown rice is milled further to create more visually appealing white rice.
- After harvesting and drying, the paddy is subjected to the primary milling operation which includes de-husking as well as the removal of bran layers (polishing) before it is consumed. In this process the rice which is obtained after milling is called raw rice.
- Another process through which rice is obtained after milling is called "Parboiling Rice."
- Rice milling losses may be qualitative or quantitative in nature. Quantitative or physical losses are manifested by low milling recovery while low head rice recovery or high percentage of broken kernel reflects the qualitative loss in rice grains.

A commercial rice miller will have following objectives:

1. produce edible rice that appeals to the customer- i.e. rice that is sufficiently milled and free of husks, stones, and other non-grain materials
2. maximize the total milled rice recovery out of paddy minimize grain breakage

To understand the different objectives of rice milling, please review the following terminology

Rough rice

Paddy/ rice. Rice as it comes from the field. Rice kernels are still encased in their inedible, protective hull.

Brown rice or husked rice

The least processed form of rice. It has the outer hull removed, but still retains the bran layers that give it a characteristic tan color and nut-like flavor. Brown rice is edible but chewier texture than white rice. Cooking time of brown rice is longer than milled rice.

Milled rice

White rice or rice after milling which includes removing all or part of the bran and germ from the rough rice.

Milling recovery

Total milled rice obtained out of paddy; expressed as weight percentage of milled rice (including broken) obtained from a sample of paddy. The maximum milling recovery is 69-70% depending on rice variety, but because of grain imperfections and the presence of unfilled grains, commercial millers are happy when they achieve 65% milling recovery. Some village type rice mills have 55% or lower milling recovery.

Milling degree

A measure of the amount of bran removed from the brown rice.

Head rice

Milled rice with length greater or equal to three quarters of the average length of the whole kernel. It is often expressed on a% paddy or rough rice basis (on 14% Moisture content basis).

Head rice recovery

Weight percentage of head rice (excluding broken) obtained from a sample of paddy. Under controlled conditions head rice recovery can be as high as 84% of the total milled rice or 58% of the paddy weight. Commercial rice mills turn out 55% head rice on average, whereas head rice recovery of village type rice mills is in the order of 30%.

Whole kernel

A milled rice grain without any broken parts

Impurities

Materials in the rice that are not part of the milled rice kernel. May include stones, husk, chaff, weed seeds, etc.

There are three requirements for producing good quality milled rice:

- 1) the starting quality of the paddy is should be good, and paddy should be at the right moisture content (14%) and have a high purity
- 2) the rice mill should be clean and well maintained, and
- 3) the mill should be operated by a skilled operator.

If any of these requirements is not met, milling will result in poor quality rice. For instance, milling of poor-quality paddy will always result in poor quality milled rice, even if a state-of-the-art mill is used or the miller is experienced. Similarly, the use of good quality paddy by a well skilled operator may result in poor quality rice if the mill is not maintained regularly. The losses in rice milling that can be attributed poor paddy quality, machine limitations, or operator innocence, is anywhere from 3 to 10% of potential.

Methods of Milling:**A) Traditional Method**

Before the advent of mechanical milling, hand-pounding traditional method of rice milling was in practice. In fact, hand-pounding rice has got more nutritive value as compared to machine milling rice. In hand-pounding, a variety of implements is used such as:

- Mortar and Pestle

- Dhenki
- Hand Stone (Chakki)

B) Mechanical Method

With the introduction of mechanized mills, hand-pounding method has steadily decreased because it could not compete with machine mills. The conventional mills in use can be categorized into three main types:

- Huller mills (about 16 metric tons of paddy per week)
- Sheller-Huller mills (about 30 metric tons of paddy per week per unit)
- Sheller-Cone Polisher mills (about 30 metric tons of paddy per week per unit)

Cleaning and Hulling

- At the processing plant, the rice is cleaned and hulled.
- At this point, brown rice needs no further processing.
- If white rice is desired, the brown rice is milled to remove the outer bran layers. Hulling is the process to remove the hull from the kernel.

A) Manual hulling: Hulling can be done by hand by rolling or grinding the rough rice between stones.

B) Mechanical hulling:

- The rough rice is first cleaned by passing through a number of sieves that sift out the debris. Blown air removes top matter.
- Once clean, the rice is hulled by a machine that mimics the action of the hand held stones.
- The shelling machine loosens the hulls from the rice. About 80-90% of the kernel hulls are removed during this process.
- From the shelling machine, the grains and hulls are conveyed to a stone reel that aspirates the waste hulls and moves the kernels to a machine that separates the hulled from the unhulled grains.
- By shaking the kernels, the paddy machine forces the heavier unhulled grains to one side of the machine, while the lighter weight rice falls to the other end.
- The unhulled grains are then siphoned to another batch of shelling machines to complete the hulling process.

Polishing

- Polishing is the process of removal of bran layer in brown rice.
- After harvesting and drying, the paddy is subjected to the primary milling operation which includes de-husking as well as the removal of bran layers (polishing) before it is consumed.
- The rice obtained after this process is called raw rice.

Whitening

- In the process of whitening the silver skin and the bran layer of the brown rice are removed.
- In the process of polishing the whitened rice, the bran particles still sticking to the surface of the rice are removed, and the surface of the rice is polished to give it a shiner appearance.

Glazing

- Glazed rice is rice that appears shinier and more transparent because the surface is coated with a thin layer of talc and glucose.
- Glazing machines are not installed as a section of rice mill but are installed as an independent unit in a separate building or location. The main machine in the glazing plant is a large, horizontal, rotating glazing drum.

Quality and Grading

- Quality of rice is not always easy to define as it depends on the consumer and the intended end use for the grain.
- Grain quality is not just dependent on the variety of rice, but quality also depends on the crop production environment, harvesting, processing and milling systems.

Characteristics Considered for Grading of Milled Rice

- Dead rice and broken percentages
- Defectives (immature grain, discolored/ yellow kernel, red kernel)
- Foreign matter and admixture of other varieties
- Presence of paddy
- Whiteness
- Chalkiness
- Moisture content
- Degree of milling

Objectives of establishing standards and grades

- To ensure only edible rice reaches the consumer.
- To improve post-harvest practices so as to eliminate or reduce waste.
- To improve agronomic practices to increase farm yields.
- To improve processing practices for better milling recoveries and for market expansion.
- To protect consumers from price/quality manipulation.

Classification of rice

Rice has been classified by the FAO based on its size and shape, namely, slender, medium, bold (coarse) and round, according to the milled kernels' length/breadth ratio.

The length-breadth ratio of slender, medium, bold (coarse) and round grain are more than 3, 2.4 to 3.0, 2.0-2.39 and less than 2.0, respectively.

Storage

Storage is the process of keeping grains, whether in bags or in bulk, in a storage structure designed to protect

the stored product from inclement weather and pests for a short or long period of time to await processing or movement to other location.

Grains are stored for either of the following reasons:

- To provide uniform supply of food throughout the year, because grains are produced seasonally while consumption is fairly uniform throughout the year.
- To provide reserve for contingencies such as flood, drought and other calamities.
- To speculate on a good price either in domestic or in the export market.

Requirement of a good storage system

- Prevention of moisture re-entering the grain after drying.
- Protection from insects, rodents and birds.
- Ease of loading and unloading.
- Efficient use of space.
- Ease of maintenance and management.

The grains are stored at three different levels, such as:

- Producer's Level
- Trader's Level
- Urban Organizational Storage Level

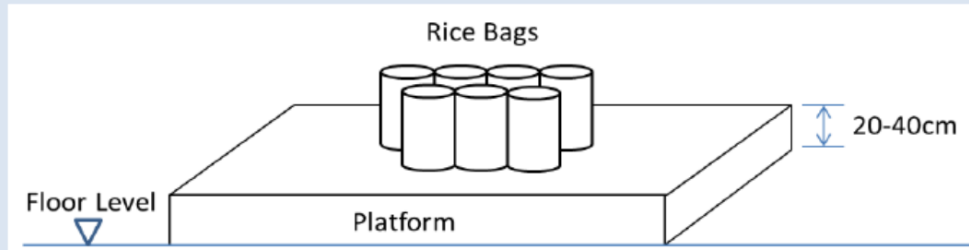
The methods followed for storing the grains are:

- A) Storage in bags
- B) Loose storage

- Storage in bags is convenient for short term storage, where grain is intended for very early onward movement.
- For short term storage, no control measures against insects are needed. In loose/bulk storage method, large quantity of grains can be stored in per unit volume of space and the infestation of insects/pests is lower.
- The basic requirements of a good storage practice are a healthy, clean, and uniformly dried grain, and a structure that will maintain a suitable environment that will prevent pests.

Further Explanation:

- (1) Adequate air ventilation is required in store rooms to prevent the moisture from floor or ground reaching the rice bags store on the floor.



- (2) Losses from insects, rodents, birds and moisture uptake are usually high in bulk storage systems. Also, some shrinkage occurs by long term storage.
- (3) Grain is protected from re-absorbing by rain or absorbing moisture from the surrounding air.

Present commercial storage situation in Asia

➤ Commercial bag storage system

- Open to atmosphere
 - moisture uptake,
 - pest problems
- Store in batches
- Clear headways and walkways
- Relatively easy to fumigate

➤ Commercial Bulk Storage

- Not popular in Asia
- Efficient use of space
- Easy to control pests? - sealed for fumigation
- Less problems with rodents and birds

➤ Commercial hermetic system

- Grain stored in bags
- Protected against moisture uptake and insects
- Rat and animal damage? -no
- Use as harvest management aid
- Need O₂ monitoring

- Big potential in Tropical areas
- 5-300 metric tons

Packaging for Post-Harvest Rice

- Good packaging provides not only convenient handling in transportation and storage but also attracts consumers to pay more attention.
- Packaging is essential to avoid spoilage and to prolong the quality of rice.
- Packaging of paddy/rice is also important for long-term storage to fulfill the demand of old rice in the market.
- In present scenario, branding and labeling of rice has significant impact on consumer preference. More care is required in packaging of rice meant for export.
- Packaging of the rice can also include elements such as transparent, colorful and attractive packaging to attract consumers.

Specification of Packaging for postharvest rice

- It must fully protect the rice and long lasting.
- It must be clean and hygienic.
- It must be convenient to handle and can be carry out from the store easily.
- It must attract the consumer.
- It must be easily identifiable.
- It must resist spoilage.
- It must tell information about rice i.e. name and address of packer, pack-size (quantity), quality (grade), variety and date of packing.

Qualities of good packaging material:

- It should be convenient in operations.
- The packaging material must preserve the quality of produce.
- It should be convenient to stack.
- It should be able to prevent spoilage during transit and storage.
- It should be cost-effective.
- It should be clean and attractive.
- It should be biodegradable.
- It should help in checking adulteration and be free from adverse chemicals.
- It should be helpful in marketing

Packaging material used in packaging of paddy/rice

- Jute bags
- HDPE / PP bags

- Polythene impregnated jute bags
- Poly pouches
- Cloth bags

Packaging requirements

Rice may be packaged in sizes of between 1kg and 50kg. The actual size will usually depend on the market for which it is being prepared. Plastic and jute are usually used for package for packing postharvest rice. Whatever the material used, the following measures are recommended:

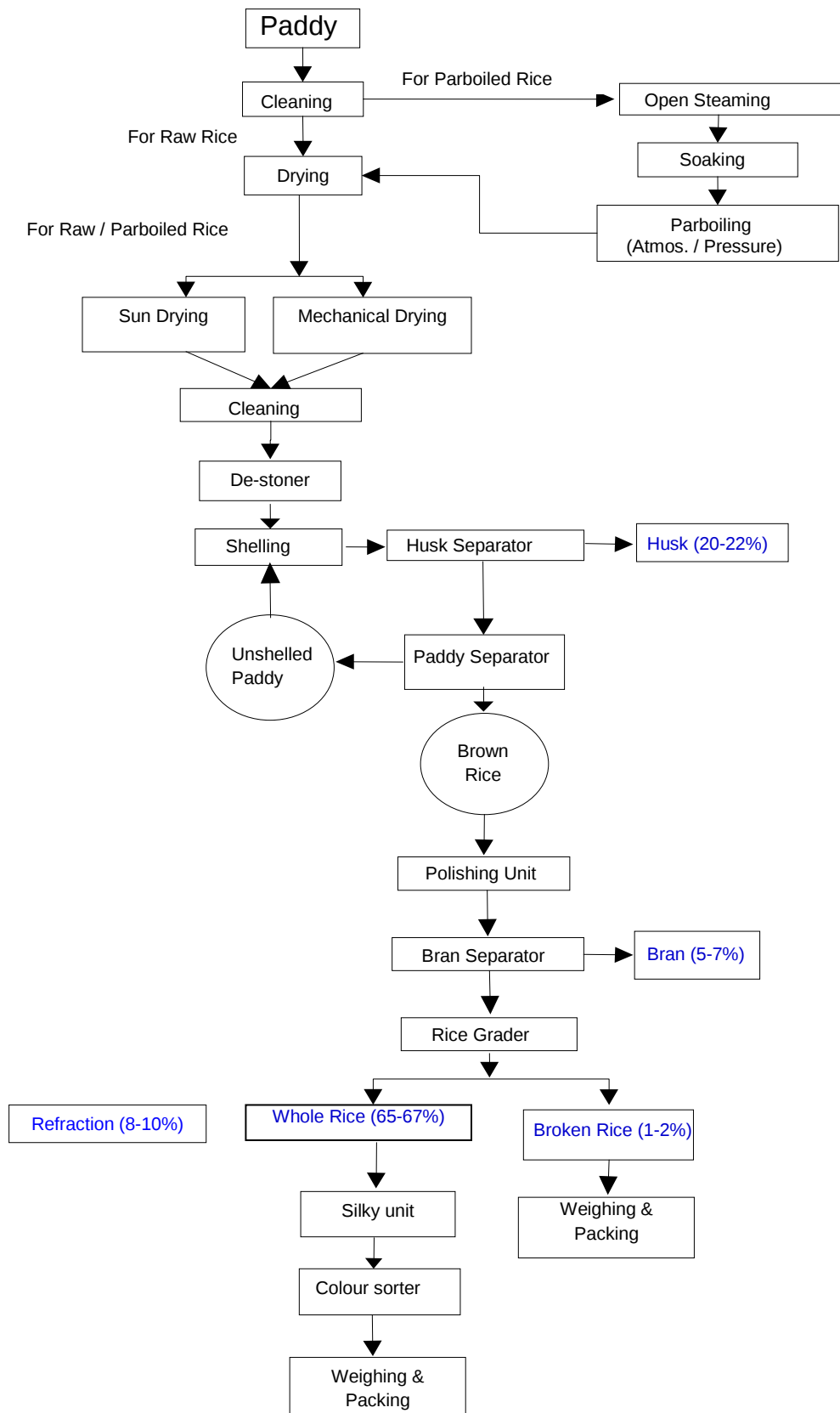
- The density of packaging material and the appearance should be appropriate. In case of propylene material, the size of the tape should be maximum 2 to 2.5 mm in width with density of 40 tapes per 10 cm. This will ensure solidity and protection against contamination.
- Size should be 55 x 95 cm to package 50 kg of rice or 45 x 75 cm for 25 kg of rice.
- For packaging of one to five kg, either polyethylene or jute could be used. The packaging material should be well designed to facilitate the handling and transportation by consumers.

Method of packing

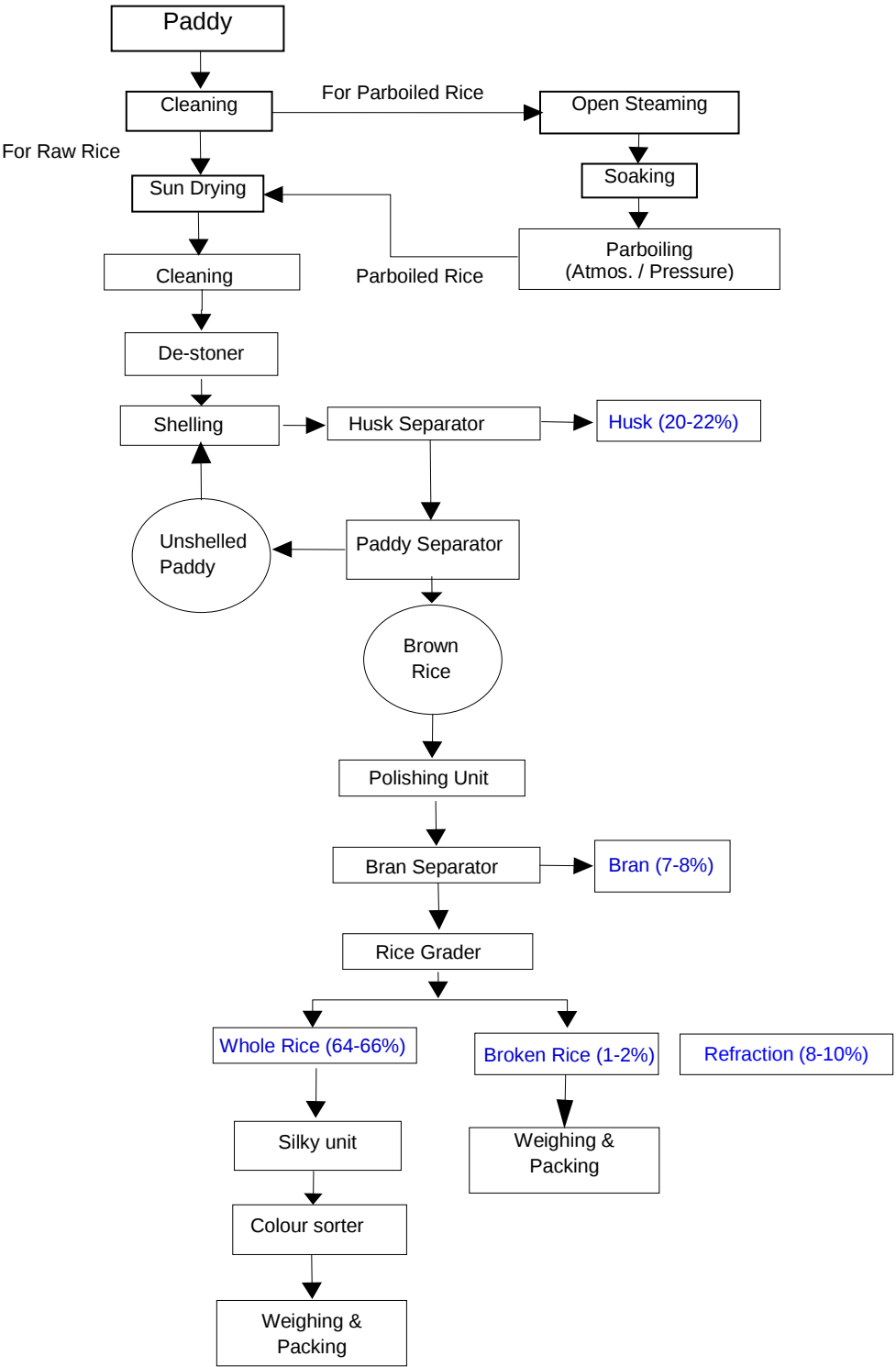
- The graded rice should be packed in new, clean, sound and dry jute bags, cloth bags, polywoven bags, polyethylene, polypropylene, high molecular high-density polyethylene paper packages or in other food grade plastic/packaging materials.
- The packages shall be free from insect infestation, fungus contamination, deleterious substances and undesirable or obnoxious smell.
- Each package shall be securely closed and suitably sealed.
- Each package shall contain rice of one grade only.

Over 90% of the rice in Bangladesh is parboiled before milling. In terms of milling capacity, this is adequate for the country, but the quality of milling needs to be improved through introducing/incorporating a two-stage milling system and ancillary processing equipment. This improvement in milling technology will reduce milling losses to a great extent and will provide the nation additional milled rice out-turns compared to the same quantities of paddy currently being processed by inefficient mills. In addition, by improving the quality of rice to conform to international standards, it will create opportunities for exporting quality rice in the international market.

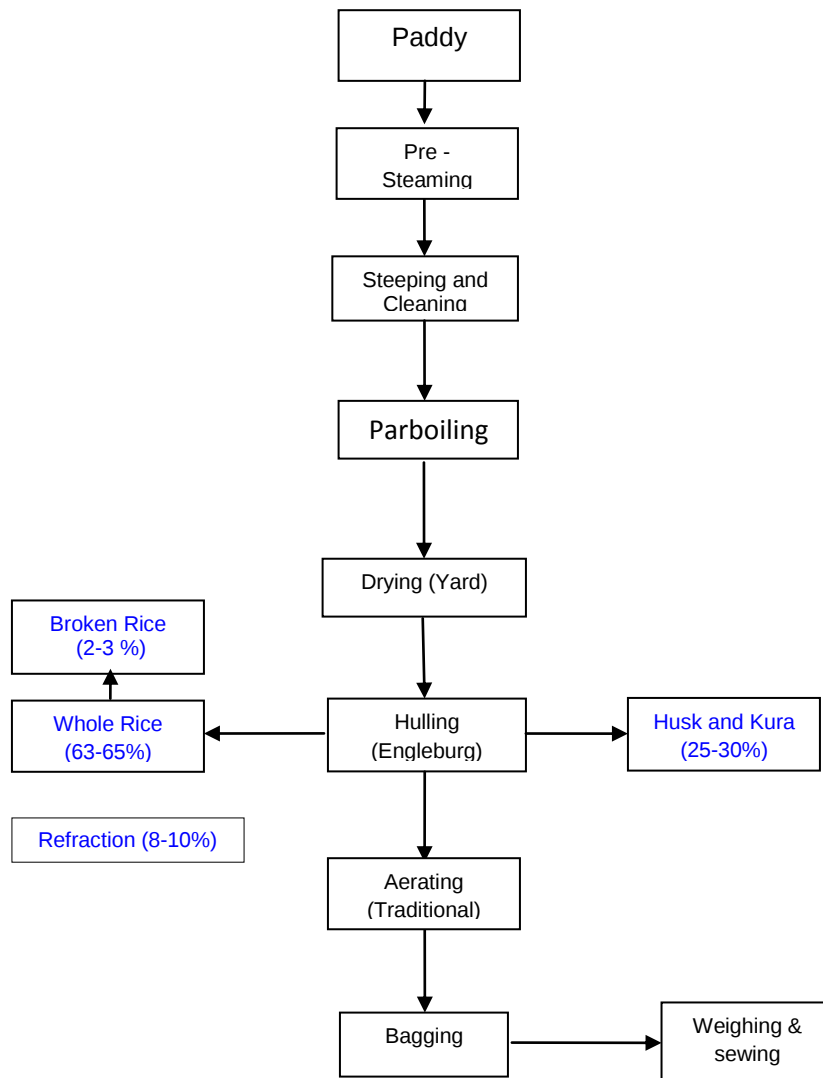
FLOW CHART FOR AUTOMATIC RICE MILL

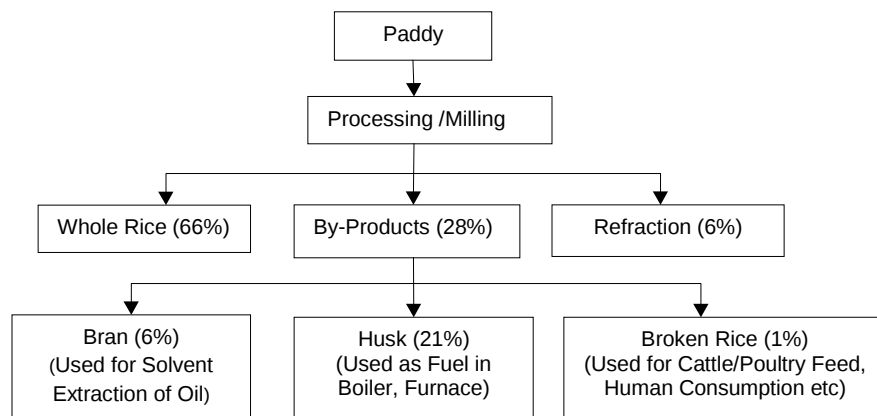


FLOW CHART FOR SEMI- AUTOMATIC RICE MILL



FLOW CHART FOR HUSKING RICE MILL





Rice Products

By Products of Rice

- Modernization of rice milling Industry also results in production of quality by-products viz., broken rice, husk and rice bran.
- Technology is now available to produce value- added products from these by-products.

Broken rice

- The broken rice is widely used in the food preparations and in the industries for making flour and in the manufacture of baby foods.
- The starch extracted from broken rice finds wider application in the pharmaceutical, textile and other industries.

Rice husk

- Rice husk that contains about 38% cellulose and 32% lignin and is one of the most abundant renewable agriculture-based fuel materials.
- The production of rice husk is about 80 million tons per year, equivalent in energy to about 170 million barrels of oil.
- Paddy husk contains about 22 percent ash of which 95 percent is silica.
- Because of its high silica content, it is used as an abrasive. Large quantities of husk are used in Bangladesh as fuel for boilers, kilns and household purposes.

Rice Husk – A Useful By-Product for Rice Growers.

Products from Rice Husk.

List of Profitable Business Ideas of Rice Husk, Rice Hull, Rice Husk Ash (Agricultural Waste) based Projects, Waste to Wealth.

(Precipitated Silica, Activated Carbon, Cement, Electricity, Ethanol, Hardboard, Oxalic Acid, Paper, Particle Board, Rice Husk Briquettes, Rice Husk Pellet, Silicon, Sodium Silicate Projects)



www.entrepreneurindia.co

Rice straw

- Each tone of paddy produces an equal amount of straw as by-products.
- Straw can be used as ruminant fodder, stable bedding material, raw material in mushroom cultivation and industrial processes like papermaking etc.
- It is also used as fuel for cooking.
- Paddy straw is used as substrate for Mushroom production. For 100 kg Mushroom production - Dry paddy straw (not more than one year old) -100 kg is required. **Preparation of Substrate**-Use Dried paddy straw, 500 gms per bed. Cut the paddy straw into small bits of 3 to 5 cm. and soak it in cold water for 6-8 hours. Take it out and then immerse in boiling water for 15-30 minutes and drain off excess water. Dry the straw in the shade for 2 hours and then use.

Rice bran

- Commercially rice bran is the most valuable by-product, which is characterized by its high fat (15 to 20%) and protein content (12%).
- Because of its nutritional value, it is being used as feed for poultry and livestock.
- More stable defatted bran containing higher percentage of protein, vitamins and minerals is an excellent ingredient for both food and feed.
- It is generally contaminated with husk, which lowers its nutritive value.

Rice bran oil

- Bran oil is obtained by the extraction of rice bran with solvents.
- The oil contains a high percentage of unsaturated fatty acids, yet it is quite stable because of the presence of natural antioxidants.
- When refined, bleached and deodorized, it is used for salad dressing and as cooking oil.
- Bran after solvent extraction has a higher percentage of protein than the original material. With its low-fat content, it keeps well.

The flow chart of rice bran oil processing plant is as following:

Raw material (rice bran) →magnetic separation →floury product separation →quenching and tempering → puffing (extrusion machine) →drying and cooling →solvent extraction plant →refining plant →dewaxing plant →high quality refined oil

Importance of rice bran oil

- Rice bran oil contains components of vitamin E that may benefit health.
- The unique components, such as or tocotrienol, have been drawing people's attention.
- Oryzanol reduces the harmful cholesterol (LDL) without reducing good cholesterol (HDL).

- Tocotrienol, is highlighted as the most precious and powerful vitamin E existing in nature and is said to have an anti-cancer effect.

VALUE ADDITION

1. Processed Products
2. Fermented Products Based on Rice
3. Extruded Products

1. RICE - PROCESSED PRODUCT

Parched rice

- It is prepared by throwing rice in sand heated to a high temperature in an iron or mud pan.
- On stirring, rice begins to crackle and swell. Then the content of the pan is removed and sieved to separate the parched rice from sand.
- Parboiled rice is used for making grayish to brilliant white color parched rice and sold either salted or unsalted.

Expanded rice (Muri)

- Expanded rice (murmura, pori, muri, urum) is a traditional convenience food widely consumed in Bangladesh.
- In the traditional process, the paddy is soaked in water preferably over night until saturation, drained and then either steamed or dry roasted in sand for parboiling.
- The parboiled paddy is milled, salted and again roasted in sand for expansion.

Puffed rice:

- This popular ready-to-eat snack product is obtained by puffing milled parboiled rice.
- In the traditional process rice is gently heated on the furnace without sand to reduce the moisture content slightly.
- It is then mixed with salt solution and again roasted on furnace in small batches with sand on a strong fire for a few seconds to produce the expanded rice.
- Rice expands about 8 times retaining the grain shape and is highly porous and crisp.

Puffed rice from parboiled rice

- The rice is soaked in salt water to increase the moisture to about 20%.
- The moist rice is introduced into a hot vessel at about 250-275°C for 30-40 seconds.
- The rice puffs suddenly.

Popped rice

This is prepared from raw paddy. The paddy at a moisture content of 12-14% is directly roasted in iron pans using sand as a medium at a temperature of 150-200°C.

Flaked Rice

- Flaked rice is value added product prepared from paddy.
- Traditionally, it is prepared from soaked paddy, after heat treatment and immediate flattening using a flaking machine (an edge runner).
- Flaked rice is thin and papery and of white color.

Flattened rice

- Flattened rice, commonly known as Chira, is rice, which is flattened into flat, light, dry flakes originating from the Indian subcontinent.
- This easily digestible form of raw rice is very popular across India, Nepal and Bangladesh, and is normally used to prepare snacks or light and easy fast food in a variety of Indian cuisine styles, some even for long-term consumption of a week or more.
- These flakes of rice swell when added to liquid, whether hot or cold, as they absorb water, milk or any other liquids. The thickness of the flakes varies between almost translucently thin (the more expensive varieties) to nearly four times thinner than a normal rice grain.

Quick cooking rice

Quick cooking rice is made by steeping polished rice in water to a moisture content of 35 percent, cooking under pressure and drying.

Derived products

Polished rice may be precooked and canned as rice pudding and also used to make dry breakfast cereals.

2. RICE - FERMENTED PRODUCTS

Idli

- Idli is a small, white acid – leavened, and steamed cake made by bacterial fermentation (12-18 hours) of a thick batter made from rice and dehulled blackgram dhal.
- Idlies are soft, moist and spongy had a desirable sour flavour.
- For idli, the rice was coarsely ground, and the black gram was finely ground.

Dosa

- Dosa is another common fermented product used in Indian subcontinent.
- This is prepared from a fermented batter of rice and pulse in the proportions ranging from 6:1 to 10:1.
- Both the ingredients are finely ground, unlike in the idli batter which contains the rice component in a coarse consistency.
- The dosa batter is very thin and dosa is baked on a hot pan.

3. RICE- EXTRUDED PRODUCTS

- Extrusion is a process that combines several unit operations including mixing, kneading, shearing, heating, cooling shaping and forming.
- It involves compressing and working raw material e.g. Flours, starches, proteins, salt, sugar and other minor ingredients to form a semi solid mass under a variety of controlled conditions and then forcing it to pass through a restricted opening such as a shaped hole or slot at a predetermined rate.
- Heat is applied directly by steam injection or indirectly through a heated barrel.
- The final process temperature in the cooking extruder can be high as 200°C but the time of exposure to heat is relatively short (10-60 seconds).
- The extrusion cooking is also called a high temperature short time (HTST) process.

Extruded products

- Rice based extruded products include sevai, idiappam, murukku (chakli) rice based vadagam etc.
- Rice based noodles and noodles from fermented rice flour are popular.

Idiappam

Idiappam is a traditional food prepared from the combination of parboiled rice and raw rice. It is consumed as breakfast / dinner for the peoples especially South Indians. It is a steamed product and consumed as either in the form of sweet or savoury dish.

Murukku

Raw rice and black gram were ground in a mill separately and sieved through 80 BS sieve and used for the preparation of murukku instant mix.

Vadagam

The ingredients were mixed, and 250 ml of water was added and cooked for 10 minutes until a thick extrudable paste was formed. The hot paste was extruded in hand extruder (dia 5 mm) and dried in sun for about five hours. The dried vadagam sample was packed in a polyethylene bags and sealed.

CAKE OR PITHA

- Bangladesh is called the country of 'Pitha-puli'.
- The traditional pithas of Bangladesh have been widely appreciated for its fabulous tastes.
- Pitha is a type of rice cake in Bangladesh.
- Some Pithas are associated with harvest festival (Nobanno, Poush-Parbon)

Ingredients: Rice flour (Selective), Sugar, Milk, Egg, Vanilla essence, lubricating agent such as Sagu powder, guar gum, aloe vera or barley, Butter, Plum oil, Yeast powder, Rice Bran Oil (RBO) and Vegetable edible oil.

LIST OF SOME COMMON PITHA IN BANGLADESH

1.Teler pitha 2. Bapa pitha 3. Bhijano pitha 4. Semai pitha 5. Puli pitha 6. Dudpuli 7. Pakon pitha 8. Nokshi pitha 9. Chittoi pitha 10. Golap pitha 11. Narikeler chondropuli 12. Bindani 13. Chushi 14. Lobongo latika 15. Bibikhana 16. Dolla 17. Patisapta 18. Chidruti,etc.

Constrains:

- Lack of stickiness (gluten protein) in rice flour followed by uneven texture.

Considerations to overcome the constrain:

- Milled rice should be treated for 1 hour soaking in water at room temperature before grinding into flour.
- Parboiled rice of should be used for rice-based bakery products subjected to Diabetic patient.
- Low apparent amylose content (AAC) and GT content rice flour is mostly suitable for rice-based bakery products.
- Sheaving flour to attain unique flour size seems necessary.
- We consider guar gum, sagu, barley and aloe vera as thickening, stabilizing, suspending, and binding agent.

Energy Dense Rice Cake (EDRC) and Rice Biscuit (EDRB)

What are these products? - Rice-based biscuits and cake which provide approximately 500 kcal with a minimum of 10 grams and max of 15 grams of protein per 100 grams.

When and where are these products supposed to be used? -In the first days of emergency when cooking facilities are scarce. Easy to distribute and provide a quick solution to improve the level of nutrition.



BRI Developed Rice Based Diversified Food Products

Bakery Products.	Energy dense biscuit (500-550 Kcal 100g⁻¹)
Gluten free (Allergen free) anti diabetes Rice Bread.	Emergency relief operation.
Plain, fruits & dry cake.	Dry food supply in flood situation.
Cookies & Rice ball.	Food supplement in war situation.
	National Malnutrition mitigation program.
	National level food for work program.

Merits of rice based food items depends on following properties and attributes

Nutraceutical properties such as Iron, Zinc (Enzymes cofactors), Anthocyanin(Anti cancer), GABA (Anti depressive), Low GI (Anti-diabetes), Antioxidant (Immunity enhancer), Dietary fiber and Protein enriched rice flours are purposefully used for formulation and manufacturing rice based food products at BRI.

BRI has Identified Nutraceutical rice varieties such as BR5,BR16,BRI dhan34, BRI dhan42, BRI dhan43, BRI dhan46, BRI dhan62, BRI dhan64, BRI dhan69, BRI dhan72, BRI dhan74, BRI dhan84 & Black rice.



Contact details: Grain Quality and Nutrition (GQN) Division, Bangladesh Rice Research Institute (BRI), Gazipur-1701. Email: head.gqn@bri.gov.bd, habibul.gqn@bri.gov.bd